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A model assessment of satellite observed trends in polar sea ice extents

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Abstract

For more than three decades now, satellite passive microwave observations have been used to monitor polar sea ice. Here we utilize sea ice extent trends determined from satellite data for both the Northern and Southern Hemispheres for the period 1972(73)–2004, and assess and interpret them using results from simulations by eleven climate models. In the Northern Hemisphere (NH), observations show a statistically significant decrease of sea ice extent and an acceleration of sea ice retreat during the past three decades. However, from the modeled natural variability of sea ice extents in control simulations, we conclude that the acceleration is not statistically significant and should not be extrapolated into the future. Most of the models, like the observations, show an absence of a prominent seasonal cycle in the trend values. Both observations and model simulations show that climate variability in sea ice extent in the Southern Hemisphere (SH) is much larger than in the NH and that the SH sea ice extent trends are not statistically significant.

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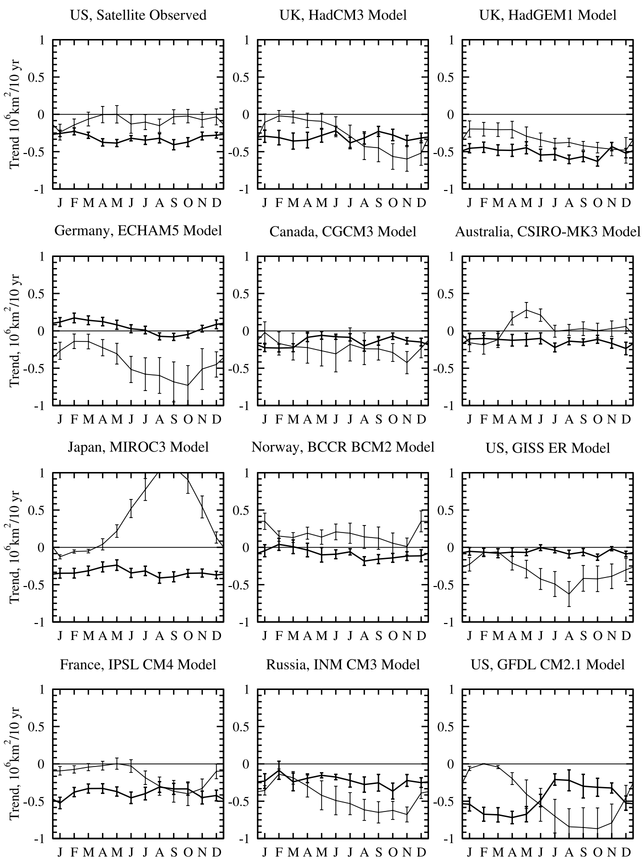

Figure 2. Seasonal cycle of observed and model simulated 1972(73)–2004 trends in Northern (thick lines) and Southern Hemisphere (thin lines) sea ice extents. Vertical bars show standard errors of trend estimates.

been developed and tested earlier by *Stouffer et al.* [1994] and *Vinnikov et al.* [1999]. This approach estimates the frequency of occurrence of trends that exceed the observed one in a model simulated time series and provides a probability based on the assumption that the expected value of a trend is close to zero and that the sampling variability has a normal statistical distribution. If the observed trend exceeds twice its standard error then it is considered here to be statistically significant. The parameters given in Table 1 can be used with other thresholds of statistical significance. Table 1 also gives the length of available multi-centennial control simulations for each of the models (***N***) and the percent occurrences of trends (***P***) that exceed the observed trends in moving windows of length 32–33 years through the multi-centennial runs.

[7] Comparing the climate model simulations with the observations:

[8] (1) Satellite observed annual mean multi-year averages for 33–32 years of sea ice extents (α) are almost equal in both hemispheres ($11-12 \cdot 10^6$ km^2). About half of the models agree that the annual average sea ice extents in the two hemispheres do not differ much for the present-day climate. We cannot talk about statistical significance of this difference, because models continue to drift over their internal equilibrium states. The hemispheric results for the other half of the models differ considerably.

[9] (2) The observed standard deviation of detrended annual mean sea ice extents ($\boldsymbol{\sigma}$) in the NH ($0.16 \cdot 10^6$ km^2) is much smaller than in the SH ($0.38 \cdot 10^6$ km^2). All the models agree with the larger interannual variability of sea ice extents in the SH versus NH, but the observed variability is near the low end of the model simulated variability in both hemispheres. More representative estimates of modeled natural variability of sea ice extents $\langle\boldsymbol{\sigma}\rangle$ were obtained from multi-centennial control simulations of the preindustrial climate than for the 33/32-year observation period by averaging variances of detrended ice extents computed in the 32–33-year moving windows. The results from some of the models suggest that the years of observation, 1972–2004, may represent a period of relatively low interannual variability of sea ice extents in the NH. However, it is possible that all of the models except two (GISS-ER and CGCM3) overestimate natural variability of NH sea ice extents.

[10] (3) The observed decreasing trend in NH sea ice extents, $\beta \approx -0.3 \cdot 10^6$km^2/10 yr, is statistically significant based on the error statistics $\boldsymbol{\sigma}_\beta$ and $\boldsymbol{\sigma}_{\langle\beta\rangle}$ for sea ice extents from most of the models. Six of the models have zero occurrences of trend that exceeds the observed trend in control runs. The largest percent occurrence is 4%, a small value that does not change the overall conclusion. The observed sea ice retreat in the SH is much weaker and statistically not significant, but the sign of the trend is reproduced in simulations of 8 of the 11 climate models. The occurrence of a trend that exceeds the observed trend in control simulations of the different models varies from 15% to 46%, suggesting that natural climate variability often generates trends at least as large as the observed trend in the SH.

[11] (4) Acceleration in the rate of sea ice retreat observed in the NH is statistically significant according to calculations based on the observed data by themselves. Several of the models also obtain a statistically significant acceleration for the 1972–2004 period, although only one, GISS-ER, obtains a statistically significant acceleration from the multi-centennial run. Further, the GISS model obtains an acceleration that is approximately twice as large as in the observed data. Clearly, acceleration is necessary at some point in order to transition from a stationary sea ice regime, as seems to have existed in the NH ice cover in the first half of the 20th century [*Vinnikov et al.*, 1999], to the current rate of retreating sea ice cover.

[12] (5) As can be seen in Figure 2, the trends of sea ice retreat in the NH do not vary significantly among the months, with no strong seasonal dependence. The 1973–2004 trends in the SH are also negative, but are much smaller in magnitude than the trends in the NH and are insignificant for each month. The modeled NH trend is larger than the observed trend in some models, smaller than the observed trend in other models, but only one of the models does not reproduce a 1972–2004 NH sea ice retreat. Most of the models, like the observations, show an absence of a prominent seasonal cycle in the trend values.

4. Concluding Remarks

[13] We have attempted to place more than three decades of satellite observed polar sea ice variations into a broader statistical context by comparing them with sea ice simula-

tions from eleven state-of-the-art climate models. The simulations were used both for the time period of satellite observations (1972/73–2004) and for multi-centennial control runs of pre-industrial climate. Our results are based on only a single model simulation for each of the models, i.e., one sample from a variety of possible realizations that can be obtained using each model. Only the main components of external forcing in these model simulations are the same. On the other hand, the minor components of external forcing are not sufficiently different to explain the differences of statistics obtained from the models. Initial states of the climate system are quite different as are the sensitivities of each model. As a result, the models demonstrate a wide range of variations in simulated sea ice extents. Nevertheless, the climate model simulations provide statistical support to the conclusion that the satellite observed retreat in NH sea ice extents is a real climate change and that the retreat is a response to changes in the observed external forcing of the global climate system. An absence in the NH of a significant seasonal dependence of monthly trends, the acceleration of sea ice retreat, and the lack of a statistically significant trend observed in SH sea ice extent all deserve further investigation.

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